TAC-TR-61-73

OPERATIONAL TEST AND EVALUATION

SILVER ZINC BATTERY CELL REPLACEMENT

JUNE 1963

HEADQUARTERS
TACTICAL AIR COMMAND
United States Air Force
Langley Air Force Base, Virginia

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Silver-Zinc Battery Cell Replacement

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TACTICAL AIR COMMAND
United States Air Force
Langley Air Force Base, Virginia

FOREWORD

The authority for TAC Test 61-73, Silver-Zinc Battery Cell Replacement, is contained in Air Force Regulation 80-14, and TACR 80-1. The test was conducted at the 4th Field Maintenance Squadron, 4th Tactical Fighter Wing (TAC), Seymour Johnson AFB, North Carolina and the 4522nd Field Maintenance Squadron, 4520th Combat Crew Training Wing (TAC), Nellis AFB, Nevada.

The following individuals were responsible for the test management and compiling information for the final report.

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ABSTRACT

This test determined that individual cells could be replaced in the silver-zinc battery by field level maintenance activities. Analysis indicates that it is practical to replace cells in batteries having up to fifteen months service. Under test conditions, battery life was extended an average of 5.24 months by individual cell replacement. Maintenance techniques were developed during the test that will aid in increasing the service life of this battery. Improper use and handling was a large contributing factor to battery failure. An aggressive training program should be conducted for aircrew and maintenance personnel to reduce failures due to personnel error.

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1. INTRODUCTION: When the silver-zinc battery was initially placed in service, it was necessary to return it to the depot for all cell replacement and repair. This necessitated maintaining a large number of batteries in stock to allow for transmit time to depot for repair. In 1961, maintenance personnel of the 4520th Combat Crew Training Wing (TAC FTR), Nellis AFB, Nevada and the 4th Field Maintenance Squadron, Seymour Johnson AFB, North Carolina recommended through channels that the concept of individual cell replacement by technicians of field activities be tested. Approval for the test was obtained from the prime depot (ROAMA, Griffiss AFB, N.Y.). Testing commenced at Seymour Johnson AFB, North Carolina and Nellis AFB, Nevada in December 1961.

2. DESCRIPTION: The silver-zinc battery is rechargeable and contains fourteen individual cells. Each cell has a nominal voltage of 1.84 volts giving the battery a total voltage of 25.8 volts. It is nominally rated at 100 ampere-hours which is seven times that of a comparable lead-acid battery and twice that of a nickel-cadmium type. The dimensions are 10-11/16 inches high, 9-15/16 inches wide.

3. PURPOSE OF THE TEST: The purpose of this test was to determine the feasibility of replacing individual cells in the silver-zinc battery at the field maintenance level.

4. SCOPE OF THE TEST: The scope of the test was to determine:

a. The feasibility of increasing service life of the batteries by replacing individual cells at field maintenance level.

b. The man-hours required to replace individual cells and develop methods and techniques for replacement of cells.

c. The quantity of used cells of different age groups necessary to support repair of those batteries with over six months service.

d. At what service life batteries should no longer be repaired in the field.

e. The number of new cells to be stocked to repair batteries that require cell replacement with less than six months service.

f. Necessary changes to Technical Order 8D2-2-1, Maintenance Instructions for Silver-zinc Batteries.

5. CONCLUSIONS AND RECOMMENDATIONS:

a. Conclusions:

(1) It was determined that it is feasible to replace individual cells to extend the service life of the battery.

(2) Procedures for confirming that a cell is defective and for cell replacement were developed and have been incorporated into T.O. 8D2-2-1.

(3) An average of one man-hour is required to replace a cell.

(4) For best reliability, defective cells should be replaced by cells near the same age or less.

(5) Damage due to heat during discharge/charge operations can be reduced by utilizing refrigeration.

(6) Average service life of fifteen months can be obtained by cell replacement and strict quality control of maintenance.

(7) The failure rate percentage for each age group was determined. This data can be used to determine the quantity of new cells and used serviceable cells in each age group required to support battery maintenance.

(8) A continuing education program on this type battery is required for all aircrew and maintenance personnel to prevent inadvertent damage through misuse.

b. Recommendations:

(1) That field maintenance activities possessing the Battery Charger type RAC 999(A) be authorized to accomplish cell replacement. Only in extreme emergencies should a constant potential charger be used.

(2) Technical Order 8D2-2-1 be revised to include changes recommended by this test.

(3) That the Equipment Component List for units authorized repair of silver-zinc batteries be revised to include a refrigerator (six cubic feet or larger).

(4) Air conditioning should be provided for shops performing battery maintenance.

(5) Batteries older than six months should be stored in a fully charged condition if they are to be stored for a prolonged period. These batteries should be thoroughly checked every seven days. New batteries and those having less than six months service would be stored in a discharged condition in accordance with Technical Order 8D2-2-1.

(6) Activities which accomplish repair of the silver-zinc batteries must establish procedures for controlling and recording maintenance actions and other data pertaining to the life of the battery.

(7) That the prime depot (ROAMA) investigate the problem of battery overheating due to the high temperature encountered when installed in the aircraft.

(8) That the prime depot (ROAMA) perform a study of the individual cell discharge method; increased battery life through use of this method may justify procurement of individual cell discharge equipment.

6. TEST ENVIRONMENT: The test was conducted in the battery sub-units of the 4522nd Field Maintenance Squadron, Nellis AFB, Nevada and the 4th Field Maintenance Squadron, Seymour Johnson AFB, North Carolina. Testing started in December 1961 and data collection was continued until 1 May 1963 to determine the effect of cell replacement in the field.

7. TEST PROCEDURES:

a. The initial phase of the test was conducted by repairing batteries with cells having approximately the same activation date. It was intended to use new cells to replace unserviceable cells in batteries having less than six months service; however, new cells were not available during the period of the test.

b. A service record was established for all batteries showing serial number, date manufacturered, date activated and all installation and maintenance actions.

c. Methods were developed at each test organization for replacement of individual cells along the guide lines established by Hq TAC and the prime depot.

8. <u>TEST RESULTS AND DISCUSSION</u>:

a. No problems were encountered in individual cell replacement by either test organization. Both units reported very satisfactory results and no failures of the repaired batteries occurred while they were installed in an aircraft. This is attributed to the thorough tests performed on the battery before it was released to an aircraft.

b. There were significant differences in the average initial battery life obtained at the two test bases. The average battery life before the first failure was 11.12 months at Nellis AFB and 14.05 at Seymour Johnson AFB. The only major difference in the procedures employed at the two bases was the use of individual cell discharging at Seymour Johnson AFB. It was not determined the degree that this procedure contributed to the increased initial battery life since the different climatic conditions at the two bases must also be considered. The extremely high temperature at Nellis AFB undoubtedly contributes to the lower initial battery life at that base. The higher ambient temperature the battery is subjected to when installed in the aircraft at Nellis AFB may be a major contributing factor to the shorter life. This problem requires further investigation to determine climatic effect on battery life and if cooling should be provided for the installed battery. Conclusive data is not available in this area as it was beyond the scope of this test.

c. The specific point in service life when batteries should no longer be repaired cannot be definitely determined. This depends upon not only the service life but other factors such as number of cells that had failed, availability of replacement batteries and cells, and man-hours available to accomplish repair. Service life can be extended indefinitely by continually replacing cells. During the test, cells were replaced in batteries having as much as 30 months service. All 14 cells were replaced in one battery which had 9 months service and the service life of the replacement cells ranged from 9 to 18 months. This battery was in service 8 additional months before another failure occurred. It was found that as service life increased, the failures increased. In the older batteries, additional cells would fail before the battery

was completely checked out. The chance of failure increased rapidly for batteries with over 12 months service and few additional months of service can be expected after a battery has 15 months service. For these reasons, cells would not normally be replaced in batteries having over 15 months service.

d. An analysis of the data collected during this test reveals that battery life was extended an average of 5.24 months in those batteries returned to service after individual cell replacement. This ranged from 3.7 months for batteries having over fifteen months service to 11.8 months for those having 6 months or less service. An average service life of 18.39 months was realized from batteries which had cells replaced compared to 13.15 months average service life when cell failure first occurred. No significant difference was noted in the service life of batteries having cells replaced at the two test bases. It averaged 19.30 months at Seymour Johnson AFB and 18.22 months at Nellis AFB. These figures do not include batteries which had numerous cells fail during checkout and were salvaged. They should not be construed as the service life that would be expected under normal conditions. This data was collected under test conditions and cells were replaced in batteries having service life far beyond that normally expected. TABLE 1 shows the average number of months service life was extended by age groups.

TABLE 1. AVERAGE MONTHS SERVICE AFTER CELL REPLACEMENT

AGE GROUP	AVERAGE EXTENDED LIFE (MONTHS)
6 months and under	11.8
7 to 9 months	7.2
10 to 12 months	5.2
13 to 15 months	5.8
Over 15 months	3.7

e. The average total service life of batteries salvaged is especially significant as it shows the effect of cell replacement as well as the effectiveness of the overall battery handling, maintenance and repair program. The average service

life of the batteries salvaged at the two test bases through 1 May 1963 was 16.46 months. The actual overall increase in service life (compared to average life at first failure) was 3.31 months. The increase at Seymour Johnson AFB was only 1.67 months to an average of 15.72 months while Nellis AFB had an increase of 6.66 months to an average of 17.78 months. The notable increase at Nellis AFB is attributed to the improved maintenance procedures and to the aggressive cell replacement program carried out during the test program.

f. In analyzing the test results from the two bases, significant differences were noted in the failure pattern; 24.1% of the batteries failed at Nellis AFB with six months or less service compared to only 7.1% at Seymour Johnson AFB. 81.9% of the batteries failed with 15 months or less service at Nellis AFB compared to 68.3% at Seymour Johnson AFB. The net result was an average of 3.93 more months service at Seymour Johnson AFB than at Nellis AFB before the first failure occurred. The reasons for this wide difference could not be specifically determined. The higher average temperature at Nellis AFB is believed to be a contributing factor to the higher failure rate. The use of the individual cell discharging at Seymour Johnson AFB is possibly a contributing factor to the lower failure rate. Further analysis of the failures revealed no wide differences in failure patterns when related to calendar months. Surprisingly, most of the failures at both bases occurred during the months of March, April and May. The percentage of the total batteries in the test group that first failed in each age group is shown in Annex A. A comparison of the percentages at the two test bases is shown as well as the overall percentage.

g. The number of cells that fail in a battery is a factor which must be considered when determining at what service life batteries should no longer be repaired. It was found that batteries failing with six months or less service required replacement of an average of 1.4 cells. This ranged up to 5.6 cells for batteries having over 15 months service. Annex B shows the average number of cells replaced in batteries by age group. The number of cells in each age group is accumulative to show the increase in cells replaced as service life increased.

h. One problem recognized early in the test was the damage to the battery caused by overheating during discharge and

charging operations. Both bases developed procedures to reduce damage caused by overheating. At Nellis AFB, the 75 ampere discharge method was discontinued. Later, they procured a 33 cubic foot refrigerator and modified it to allow charging and discharging of the batteries while they were under refrigeration. Temperature was maintained near 38 degrees Fahrenheit which allowed fairly rapid discharge of the battery without overheating. At Seymour Johnson AFB, the individual cell discharge method was used which reduced the current flow through each cell minimizing the chance of overheating. This was accomplished using a special set for individual cell discharge which was designed and built by one of their maintenance personnel. Annex C contains a detailed discussion and description of the individual cell discharger.

DISTRIBUTION LIST

9AF (DMEM)	5
12AF (DM)	2
PACAF	
PFORQ	5
PFMME	2
USAFE	
OTREQ	5
MMEEA	2
OTS-R	2
USAF	
AFSSS-AC	4
AFORQ	2
ASD (ASZF)	4
AFLC (MCSDT)	4
ROAMA (RONPCS-2)	5
MOAMA (MONA1)	2
4th TFW	3
4520TH CCrTngWG	3
4500 ABW	2
4510 CCrTngWg	2
831AD	5
401 TFW	2
832 AD	5
388 TFW	2
836 AD	5
ASTIA (TIS)	1
AGOS (N-8)	1
AU (AUL3T)	1
USAF SAWC	5
USAF TARC (TACT)	5
HQ TAC	
DMEM	5
DMS	2
OIH	1
LN	4
LAR	2
LM	2
DORQ-T	10

ANNEX A

PERCENTAGE OF FAILURES/MONTHS IN SERVICE

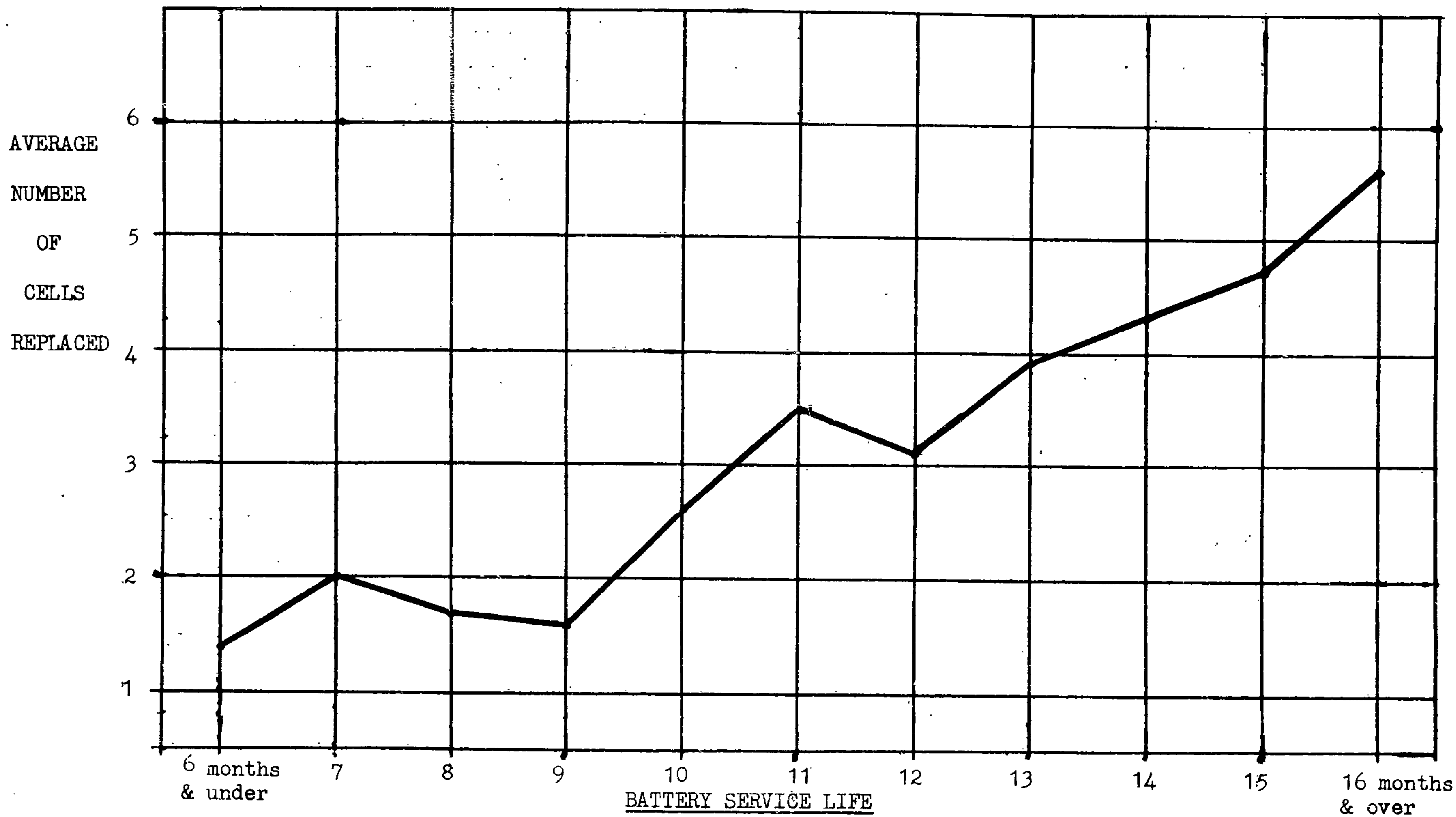
PERCENTAGE OF FAILURES/MONTHS IN SERVICE
PERCENTAGE OF FAILURES
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
(24.1)
6 months & under
7
8
9
10
11
12
13
14
15
16
17
18
19
over 20
MONTHS SERVICE
SEYMOUR JOHNSON AFB
NELLIS AFB
COMBINED AVERAGE

ANNEX A

ANNEX B

SILVER-ZINC BATTERY CELL FAILURES

SILVER-ZINC BATTERY CELL FAILURES



ANNEX B

ANNEX C

DISCUSSION AND DESCRIPTION OF INDIVIDUAL CELL DISCHARGER FOR SILVER-ZINC BATTERIES

DISCUSSION AND DESCRIPTION OF INDIVIDUAL CELL DISCHARGER FOR SILVER-ZINC BATTERIES

1. The individual cell discharger was designed to provide a convenient method of discharging silver-zinc batteries without causing damage to the individual cells. This discharger provides:

a. The discharge of one to fourteen cells.

b. Controlled current flow not exceeding 10 amperes per cell.

c. Accurate and convenient monitoring of voltage during discharge.

d. Elimination of "cell reversal".

2. Technical Order 8D2-2-1 specifies the use of Charger type RAC 999(A) to discharge silver-zinc batteries. This charger has a 20 ampere and a 75 ampere loadbank. The 75 ampere loadbank is used when discharging a fully charged battery (25 volts or higher). The voltage must be closely monitored to prevent it from dropping below 15 volts while connected to this load bank. When the battery voltage is reduced to 15-18 volts, the battery is connected to the 20 ampere loadbank. This loadbank is used to complete the discharge operation. During this period, the individual cells must be frequently checked for the first indication of zero voltage. When this occurs, the discharge must be interrupted and a short-circuit jumper placed across the cell and the discharge operation resumed. This process continues until all 14 cells are shorted. This is a very crude method and is time consuming and ineffective, particularly where there are wide variations in voltage within the individual cells. Constant monitoring of the voltage is necessary. During the discharge operation, using this type loadbank, the current flows through each of the 14 cells. Should any one of the cells drop to zero voltage, the current from the other cells would continue to flow through that cell causing a "cell reversal". Any cell subjected to this condition will suffer serious damage when charging current is applied.

3. To eliminate the possibility of "cell reversal" and to provide a convenient method of discharging any number of cells, the idea of individual cell discharging was conceived

and a prototype discharger designed and constructed. The discharger is completely housed in a metal case measuring 24" x 11" x 9". Carbon resistors are used as a load to discharge the individual cells. In preparing a battery for discharge, all cell interconnectors are removed and the individual cell connections are connected. The need for jumpers is eliminated since short circuiting is accomplished by positioning a switch. The possibility of "cell reversal" is completely eliminated since the current circuit switch is used only to hold each cell at zero voltage. Each cell is maintained at the same level (zero voltage) until the charge cycle is started. A precision voltmeter is internally connected through a selector switch to conveniently monitor the voltage of each cell. This is used to determine when the cell-to-resistor switch should be indexed to the short-circuit position. The discharger also contains a thermostatically controlled blower to provide cooling for the carbon resistors.

4. In comparing the two methods of discharge, we find that using the RAC 999 charger method, 75 amperes flow through each cell for a period of approximately one hour (assuming the battery is serviceable, requiring a periodic drain). When the voltage is reduced to 15-18 volts, 20 amperes flows through each cell until the battery is exhausted. Should any cell drop to zero voltage prior to the remaining cells, "cell reversal" may occur, unless it is immediately disconnected and short circuited by a jumper wire. Using the individual cell discharge method, not more than 10 amperes will flow through any cell and since each cell is completely independent, "cell reversal" is impossible. Further comparison shows that a fully charged battery being discharged at 75 amperes for one hour has a drain of 75 ampere hours. A fully charged battery discharged on the individual cell discharger has a drain of 10 amperes for each cell or 140 ampere hours, requiring only half the time. Even more important than the time saved is the care of the battery during discharge. Heat is a natural enemy of silver-zinc batteries and may cause boiling and gasing of the electrolyte leading to total destruction of the battery. Heat in electricity is measured in watts and is determined by multiplying volts times amperes. A fully charged battery being drained at the rate of 75 amperes with a potential of 22 volts has a wattage of 1650. A battery discharged on the individual cell discharger would dissipate only 220 watts (10 amperes times 1.57 volts times 14 cells). This difference in wattage may be the difference between preserving a battery for many months, or causing damage that would shorten its life to less than economic practicability.